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The effect of waste rubber particles and silica fume on the mechanical properties of Roller Compacted Concrete Pavement

Mansour Fakhri, Farshad Saberi. K*

Department of Civil Engineering, K. N. Toosi University of Technology, Tehran, Iran

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ABSTRACT

The current investigation discusses the potential use of recycled tire rubbers in roller compacted concrete pavement with the purpose of both improving its performance and reducing its environmental impacts. The main focus was on the basic properties of the roller compacted concrete, including the unit weight, the compressive strength, the flexural strength, and the water absorption of samples; thus, the particles of used tires were utilized as a replacement for the sand aggregate by 0, 5%, 10% … and 35%. Also, the silica fume additive was used as a replacement for the cement material in eight mixes. The main point is that fresh specimens were compacted by a hammer, not a vibrator, in order to reach a homogeneous concrete. The results of the study showed an increase in the compressive strength of 28 days for different rubber contents 5% and 10%, without silica fume, and 5%, 10%, 15% and 20%, with silica fume; however, the compressive strength was reduced for the other samples in comparison with the control specimen. Correspondingly, there was an increase in the flexural strength of 28 days for samples containing of 5% crumb rubber, with and without silica fume, although the flexural strength decreased for the other mixtures. Furthermore, the findings of the present investigation showed that the replacement of the sand by the used tire particles reduces water absorption, and this decrease was more obvious for samples with silica fume. In the final analysis, a regression model was defined to find a relationship between compressive and flexural strengths.

1. Introduction

In recent years, the growth of transportation and the use of cars have resulted an increase in tire production. Nowadays, developed countries have made a number of rules and regulations in order to prevent landfilling. In some developing countries, on the contrary, setting such rules has been far overlooked. Fig. 1 depicts the achievements of the European Union, which is provided by the European Tire and Rubber Manufacturers' Association (ETRMA, 2010). It illustrates a significant growth of recycling in the European countries from 1999 to 2009. Moreover, Fig. 2 shows the used tire treatment trends in Europe from 1996 to 2011.

The stocked pile tires have a significant potential to make numerous hazardous environmental problems such as burning, Fig. 3. In fact, when large tire piles are burnt, they release such black fume, and due to high temperature and fume, firefighters generally have a hard time extinguishing such sorts of tires. After extinguishing, it remains a kind of material, which can result a pollution in the soil and underground water. In most cases, even if stocked pile tires do not catch fire, they still can be a serious threat to the human health and the environment by providing suitable circumstances for breeding mosquitoes. In warmer climates, the mosquitoes can make such life-threatening diseases as encephalitis and dengue fever or transfer viruses like Zika around large stocked pile tires; hence, stocked pile tires can be an intrinsic danger to people and the environment (Reschner, 2008). In recent years, the researchers have performed many studies to find new methods for disposing waste tires.

The used rubbers can be utilized as a material in asphalt pavements. They present some advantages for paving such as reducing traffic noise, lowering maintenance cost, and increasing pavement life (Amirkhanian, 2001). Also, during the recent decades, many researchers have studied the different applications of the used tires in the concrete; hence, a new type of concrete has been nominated as Rubcrete.[1] The results of previous studies indicate that the

* Corresponding author. Tel.: +98 918 367 8682.
E-mail addresses: Saberi.Farshad@gmail.com, Saberi.Farshad@mail.kntu.ac.ir (F. Saberi. K).

[1] Rubcrete = Rubber + Concrete.

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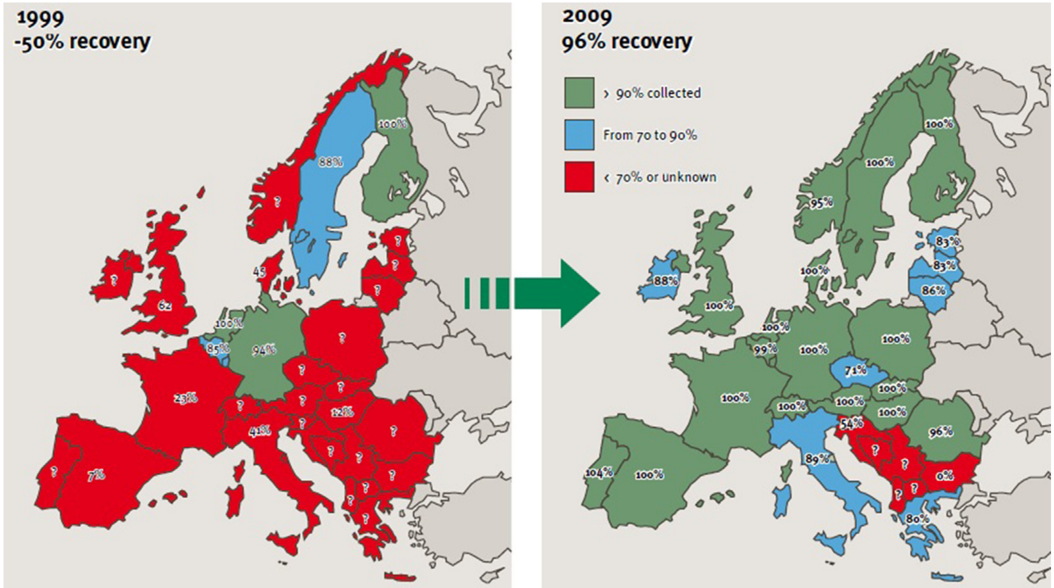

Fig. 1. The growth of recycling tire in the European countries (1999–2009).

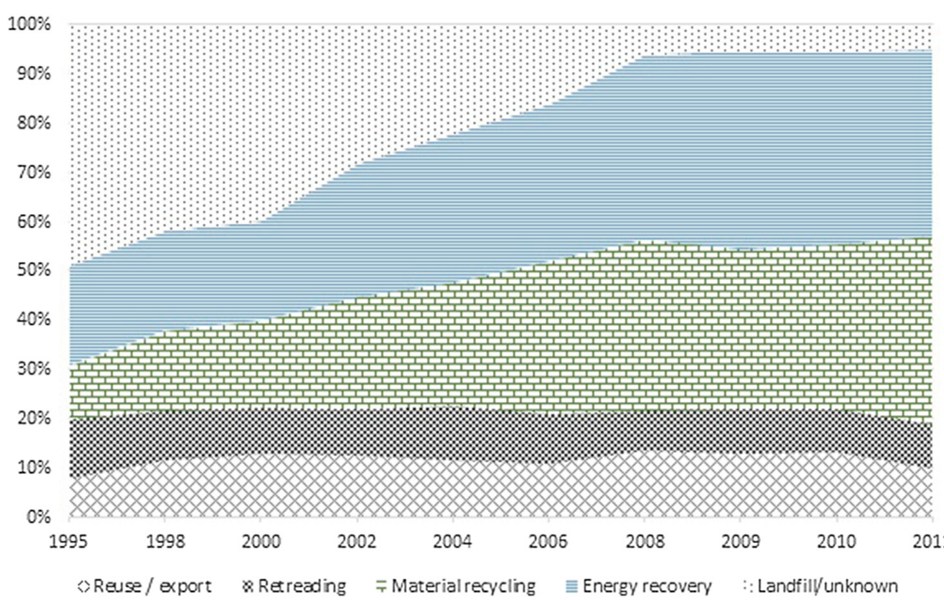

Fig. 2. Treatment routes for used tires in European countries (1996–2011).

Fig. 3. One of the stocked pile tires in France.

mechanical strength properties are reduced by increasing rubber particles in the concrete (Eldin and Senouci, 1993; Topcu, 1995; Fattuhi and Clark, 1996; Raghavan et al., 1998). Based on the studies of Eldin and Senouci (1993) the rate strength loss for coarse rubber aggregate is more than fine rubber aggregate. There was 85% reduction in compressive strength when the coarse natural aggregate were replaced by rubber aggregate, and this loss was 65% when the fine natural aggregate were replaced by rubber aggregate.

Also, Ganjian et al. (2009) worked on two sets of rubber concrete mixes with different percentages of rubber aggregate (5%, 7.5%, and 10%). In the first set, the coarse natural aggregate were replaced by chipped rubber while in the second set, the cement was replaced by scrap–tire powder. Although meager, based on the findings, the compressive strength was increased by replacing 5% chipped rubber concrete. In total, chipped rubber concretes showed a higher compressive strength in comparison with ground rubber concretes.